CERTAIN PROPERTIES OF PAPREG AS AFFECTED BY LAMINATING PRESSURE, RESIN CONTENT, AND VOLATILE CONTENT

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CERTAIN PROPERTIES OF PAPREG AS AFFECTED BY LAMINATING PRESSURE, RESIN CONTENT, AND VOLATILE CONTENT[1]

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Preliminary experiments, previously reported by the Forest Products Laboratory[2] indicated that certain trends exist between laminating pressure, resin content, and volatile content of resin-impregnated paper and some of the properties of papreg.[3] Results of a more thorough investigation of these variables are presented in this report.

TEST MATERIAL

The base paper (M. R. 2037) used in these experiments was made on the Forest Products Laboratory experimental paper machine from a commercial Mitscherlich spruce sulfite pulp especially developed from Laboratory specifications for this purpose. The significant physical properties of this paper are:

Ream weight (25x40-500)	pounds	31.0
Thickness	mils	2.5
Porosity (Gurley)	seconds	9
Density	grams per cc.	0.69
Tensile, in machine direction	pounds per square inch	11,900

[1]This mimeograph is one of a series of progress reports prepared by the Forest Products Laboratory to further the Nation's war effort. Results here reported are preliminary and may be revised as additional data become available.

[2]"Effect of Laminating Pressure on Certain Properties of High-strength Paper Plastic," Mimeograph No. 1394, March 1943. (Restricted)
"High-strength Laminated Paper Plastics for Aircraft," Mimeograph No. 1395, revised April 1943 (Restricted)

[3]The name "papreg," identifying the experimental high-strength laminated paper plastic developed by the Forest Products Laboratory has been sent to the U. S. Patent Office for registration.

Tensile, across machine direction------pounds per square inch		4,490
Tensile, average------------------------pounds per square inch		8,195

The base paper was impregnated with a spirit-soluble phenolic resin (Bakelite BV-16526). In this report the term "resin content" refers to the difference in weight, between an area of the air-dry paper and an equal area of the paper immediately as it emerges from the impregnator drying tunnel, expressed as a percentage of the treated-paper weight. The volatile content as used in this report refers to the difference in weight between a resin-treated sheet immediately as it emerges from the impregnator drying tunnel and its weight after drying in an oven at 160° C. for 10 minutes, the weight difference being expressed in percent of the first weight.[4] Therefore, the volatile content of a resin-treated paper is included in the resin content determination. For a given content of resin solids a change in volatile content also causes a change in the resin content.

In making the resin-treated paper the conditions of operating the impregnator (fig. 1) were established by test for three resin contents, each of which included about 4.0 percent volatile content. These may be considered the basic combinations of resin solids and volatile matter. The rate of resin application, temperature of the resin bath, speed of travel of the paper, and the air velocity and air temperature in the drying tunnel, were established for the basic combinations. Increases in volatile content were then made by reducing the air temperature in the drying tunnel holding all other conditions as constant as possible. After impregnation, sheets of the treated paper were cut from the roll, assembled for molding, and immediately sealed in moistureproof paper to minimize changes in volatile content caused by contact with the air.

All panels were parallel laminated at 325° F. for 12 minutes and removed from the press while they were hot. The laminating pressures used varied from 25 to 2000 pounds per square inch. The three resin contents of the treated papers were 27.5, 34.5, and 39.3 percent. For convenience in discussion, however, these will hereafter be referred to as 27, 35 and 40 percent, respectively. Each resin content was run with three volatile contents ranging from 3.9 to 4.1, 5.3 to 5.4, and 7.1 to 7.3 percent. Hereafter these will be referred to as 4, 5.5, and 7 percent, respectively. The differences between the actual and referred-to values are within the experimental error, and insofar as plastic properties are concerned, are insignificant.

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[4] It is necessary to differentiate between this volatile content and the volatile content produced by absorption of moisture during conditioning of impregnated paper. It is recognized that two resin-treated papers having the same volatile content by test, but produced by the two methods, may yield papreg having properties that are considerably different.

The same number of sheets were used for all panels. Before molding, the weight of each paper assembly was recorded. After removal from the press each panel including the flash (extruded resin) was weighed. The flash was then removed and each panel was again weighed to determine the resin lost as flash. Because of difficulties in entirely removing the flash without also removing some of the paper, these weights can be considered only as approximations. It was recognized that the percentage of flash was dependent upon the dimensions of the panel. This determination was made on panels of about 10- by 10-inch dimensions.

Test specimens were prepared and conditioned, specific gravity was determined, and specimens were tested for tension, compression, bending, and water absorption, according to procedures set forth in "Proposed Federal Specification for Organic Plastics; General Specification (Methods of Physical Tests)" July 7, 1942.

DISCUSSION OF RESULTS

Since resin content, volatile content, and molding pressure are interdependent variables, they are considered simultaneously in the discussion of their effect upon properties of papreg. The data not only show the effect of each variable, but also indicate the relationship that exists between them. Erratic results were sometimes obtained, especially at the extreme limits of the ranges because of loss in volatile content during molding at the lowest pressure and because of excessive extrusion of resin in the high range of pressures. Erratic results at the extreme limits of the ranges indicate that for this base paper and resin the practical limits of resin content, volatile content, and laminating pressure had been reached. The properties of papreg, as affected by resin content, volatile content, and laminating pressure, are shown by the data recorded in the tables. Interpretation of this data and the discussion of individual properties is from the graphs wherein the numerical values of such properties are plotted against laminating pressures. Because the effect of resin content shows more range than do the effects of volatile content, the effect of resin content is shown by a comparison between families of curves of the same series while the effect of volatile content is shown by a comparison between the curves of the same family. Although considerable scatter is sometimes shown by the test values, especially those for laminating pressures below 250 pounds per square inch, the smoothed curves are a visual average of the test values. Due to the scatter of the plotted test values at the three volatile contents for any resin content, the relative positions of the curves, at laminating pressures below 250 pounds per square inch, are not particularly significant in the graphs of strength properties. The families of curves for water absorption and specific gravity show, in general, a more significant relation between the volatile contents for a given resin content.

Ultimate Tensile Strength

The ultimate tensile strength of papreg increased to a maximum and then remained nearly constant as the laminating pressure was increased. This was true for each condition of resin content and volatile content studied. The data are given in table 1 and figures 2, 3, and 4. Using paper with 27 percent resin content and 4 percent volatile content the ultimate tensile strength was increased from 33,000 to nearly 45,000 pounds per square inch when the laminating pressure was increased from 50 to 500 pounds per square inch. The maximum tensile strength was not appreciably increased at higher molding pressures (fig. 2). Using paper with volatile content of 4 percent and resin content of 35 percent, the tensile strength increased from 34,000 to 42,300 pounds per square inch and at 4 percent volatile content and 40 percent resin content it increased from 36,300 to 39,900 pounds per square inch over the same range of pressure (figs. 3 and 4). Although the same trend was exhibited at all resin contents the tensile strength decreased with an increased resin and volatile content. The data also show that in the low range of laminating pressure higher tensile strength was obtained by using higher resin content. When using paper with 27 percent resin content, nearly 500 pounds per square inch laminating pressure was required to produce papreg with the maximum strength but at 35 percent resin content the maximum value was reached at about 250 pounds per square inch laminating pressure. The rate of increase of tensile strength with increased laminating pressure was greater when 35 percent resin content was used than when 27 percent was used.

The effects of changes in volatile content on the ultimate tensile strength of papreg were of smaller magnitude than those caused by changes in resin content.

Ultimate Edgewise Compressive Strength

The resin content of the treated paper has a highly important effect on the edgewise compressive strength of the molded plastic as shown by the data of table 2 and figures 5, 6, and 7. The ultimate compressive strength increased as the resin content was increased. Papreg molded with 5.5 percent volatile content at 250 pounds per square inch reached an edgewise compression value of 20,000 pounds per square inch when 27 percent resin content was used, but the use of 40 percent resin content under comparable conditions increased the compressive strength to 24,100 pounds per square inch.

Although the tensile strength decreased with an increase in resin content when the molding pressures were greater than about 250 pounds per square inch, the compressive strength was, in general, increased with an increase in resin content throughout the entire range of laminating pressure covered.

For nearly all combinations of volatile and resin contents the ultimate edgewise compressive strength increased to a maximum and then remained nearly constant as the laminating pressure was increased (figs. 5, 6 and 7). For each combination of volatile and resin contents the maximum compressive strength was reached at less than 500 pounds per square inch molding pressure. When a resin content of 27 percent was used a laminating pressure of nearly 500 pounds per square inch was necessary to produce the maximum compressive strength. At the higher resin contents it was possible to develop the maximum compressive strength at a molding pressure as low as 200 pounds per square inch.

Changes in volatile content were found to affect the compressive properties of papreg to a lesser degree than changes in resin content. For a resin content of 35 percent, slightly higher compressive strength resulted when using 4 percent volatile content as compared with values obtained when using 7 percent volatile content. For instance, at 4 percent volatile content and a molding pressure of 250 pounds per square inch, the compressive strength was 23,000 pounds per square inch whereas at 7 percent volatile content the corresponding value was 21,500 pounds per square inch. At each resin content the general trend was toward lower compressive strength with increased volatile content.

Modulus of Rupture

The modulus of rupture, like the ultimate tensile and compressive strengths, increased to a maximum and remained nearly constant as the laminating pressure was increased for each condition of resin and volatile content used. The data are given in table 3 and shown graphically in figures 8, 9, and 10. Paper treated with 27 percent resin required a molding pressure of about 500 pounds per square inch to produce papreg with the maximum bending strength for that resin content. When the resin content was increased to 35 percent, the maximum strength was reached at about 250 pounds per square inch molding pressure. When a resin content of 40 percent was used the maximum modulus of rupture occurred at about 200 pounds per square inch molding pressure. The highest value of these maxima, however, occurred at the lowest resin content.

If the molding pressure is above 250 pounds per square inch an advantage is to be gained in the modulus of rupture if a low resin content is used but if molding is done at a lower pressure the advantage is gained by using a high resin content. For example, at 27 percent resin content, 5.5 percent volatile content and 1000 pounds per square inch molding pressure a modulus of rupture of 41,300 pounds per square inch resulted. A comparable panel using 40 percent resin content produced a value of 38,200 pounds per square inch indicating a gain of 8.1 percent by the use of the lower resin content. However, at 75 pounds per square inch molding pressure and the same volatile content, the modulus of rupture of the panel made when using 27 percent resin content was 31,540

pounds per square inch and when using 40 percent resin content the modulus of rupture was 33,500 pounds per square inch indicating a gain of 6.2 percent by use of the higher resin content.

At all resin contents the change in maximum modulus of rupture due to a change in volatile content from 4 to 7 percent was less than 5 percent. With laminating pressures above 300 pounds per square inch the effect of volatile content on the modulus of rupture seemed to be more pronounced at lower resin content but at the lower molding pressures the effect was more pronounced at the highest resin content.

Moduli of Elasticity in Tension, Compression, and Bending

The moduli of elasticity in tension, compression, and bending increased to a maximum and then remained substantially constant as the laminating pressure was increased for each condition of resin and volatile content used. The data are given in table 4 and the relationships are shown in figures 11 to 19 inclusive. The highest moduli were produced by papreg molded at a resin content of 27 percent. Increasing the resin content up to 40 percent caused some loss in these strength values. Increasing the resin content from 27 percent to 40 percent caused a loss of about 10 percent in the maximum moduli of elasticity in tension and compression and a loss of approximately 12 percent in the bending modulus.

The discussion of the data on ultimate tensile strength and modulus of ruptu indicated that, in the range of low laminating pressure, the use of high resin content sometimes yielded higher values than those produced by low resin content, whereas, at laminating pressures greater than 250 pounds per square inch the maximum values were obtained by the use of the lowest resin content. With the moduli of elasticity, however, the lowest resin content produced the highest moduli values over the entire range of laminating pressure used. A laminating pressure from 400 to 500 pounds per square inch was required to approach the maximum moduli for a resin content of 27 percent. At a resin content of 35 percent, a laminating pressure from 250 to 300 pounds per square inch was necessary to develop the maximum, and at 40 percent resin content only about 200 pounds per square inch molding pressure was required to produce the maximum strength.

The effect of the various volatile contents for all of the resin contents on the moduli of elasticity in tension, compression, and bending did not appear to be significant and though trends may be noted they are so small that they easily could be caused by normal variations in material or test procedures.

Specific Gravity

The specific gravity of papreg, as shown in table 5 and figures 20, 21, and 22, increased to a maximum and then remained approximately constant as the laminating pressure was increased. At 40 percent resin content a maximum specific gravity of about 1.40 was reached at 200 pounds per square inch laminating pressure and at 35 percent resin content a maximum of about 1.41 was reached at 250 pounds per square inch laminating pressure. When 27 percent resin content was used a maximum of 1.42 was approached at 500 pounds per square inch molding pressure and a trend observed toward slightly higher values by an increase in molding pressure up to 2000 pounds per square inch. It is, therefore, evident that the lowest resin content produces the highest specific gravity. This is probably because the fiber component of papreg has a greater density than the resin has.

The rate of increase of specific gravity with an increase in laminating pressure up to 500 pounds per square inch was greater as the resin content was increased. Although a fairly high specific gravity (about 1.35) can be obtained with 27 percent resin content at about 250 pounds per square inch molding pressure it is necessary to use 500 or more pounds per square inch in order to obtain a specific gravity above 1.40.

The effect of volatile content on specific gravity was more pronounced in papreg made at the low resin content than at the higher resin contents. At 200 pounds per square inch molding pressure and 27 percent resin content the specific gravity was 1.28, 1.31 or 1.34 for volatile contents of 4, 5.5, or 7 percent, respectively. However, at the same molding pressure and 40 percent resin content the specific gravity was 1.40 for each of the volatile contents.

Water Absorption

Data obtained from water absorption tests on papreg are given in table 6. Papreg made with 27 percent resin content and volatile contents of 4, 5.5 and 7 percent showed a great decrease in water absorption as the molding pressure was increased from 25 pounds per square inch to 250 pounds per square inch (fig. 23). For example, when using a volatile content of 4 percent and 25 pounds per square inch molding pressure, the water absorption was 21.3 percent but this was reduced to 6.1 percent by the use of 250 pounds per square inch molding pressure. Higher molding pressures up to 1000 pounds per square inch caused only a comparatively slight further reduction to 5 percent.

Within the range of laminating pressure used, increased volatile content caused reduction in the water absorption. This is exemplified by the values obtained with a resin content of 27 percent at 250 pounds per square inch laminating pressure, where the water absorption values

were 6.1, 5.2 and 4.3 percent for volatile contents of 4, 5.5 and 7 percent, respectively. The use of relatively high volatile content and low resin content permitted the use of lower laminating pressure to obtain papregs having equivalent water absorptions. For example, 500 pounds per square inch laminating pressure was required to produce papreg having a water absorption of 5.2 percent when using 27 percent resin content and 4 percent volatile content, whereas when the volatile content was increased to 5.5 percent the same water absorption was obtained at 250 pounds per square inch, and at 7 percent volatile content only about 125 pounds per square inch was necessary. At all resin contents the effect of volatile content on water absorption was diminished with the use of higher laminating pressures (figs. 23, 24 and 25). When 27 percent and 35 percent resin contents were used the highest values of water absorption were associated with the lowest volatile content, but when 40 percent resin content was used the variation in water absorption caused by change in volatile content was not significant.

A considerable decrease in the water absorption of papreg was obtained when the resin content was increased from 27 to 35 percent, and a further but less significant decrease followed an increase in resin content to 40 percent. At 35 percent resin content with 5.5 to 7 percent volatile content a minimum water absorption of about 3 percent was obtained at a molding pressure of 200 pounds per square inch. At 25 pounds per square inch laminating pressure the water absorption obtained at 27 percent resin content and 5.5 percent volatile content was about twice that obtained when 35 percent resin content and the same volatile content was used.

The lowest water absorption resulted from the use of 40 percent resin content, and a comparatively low water absorption obtained for this resin content throughout the entire range of laminating pressures used. Values under 4.0 percent were obtained at 25 pounds per square inch laminating pressure and were not greatly changed by additional pressure up to 2000 pounds per square inch. On the other hand a resin content of 27 percent is insufficient to produce papreg having the best water resistance, regardless of volatile content or laminating pressure.

In practically every combination of resin content and volatile content used, the water absorption was slightly increased with increased laminating pressure after a certain pressure had been exceeded. This apparent point of reversal occurred at approximately 500 pounds per square inch molding pressure when 27 percent resin content was used, at about 200 pounds per square inch with 35 percent resin content, and at 150 to 200 pounds per square inch with 40 percent resin content. As the volatile content was increased for a given resin content, the trend of the effect was to move this minimum point in the direction of lower laminating pressure. This reversal in water absorption is explained by the tendency for resin to be extruded during molding when the higher ranges of resin content, volatile content, and laminating pressure were used. Approximate values for resin losses as flash are given in table 6.

These data show that over 11.5 percent of the weight of a molded panel was lost as flash when 40 percent resin content, 7 percent volatile content, and 1000 pounds per square inch molding pressure was used. For this extreme condition the total amount of resin lost was about 25 percent of the total resin applied to the paper. At the opposite extreme of resin and volatile contents, namely 27 percent resin content, 4 percent volatile content, and 1000 pounds per square inch molding pressure, the percent of the weight of the molded panel lost as flash was only 0.8 percent or approximately 3 percent of the total resin applied to the sheet.

Conclusions

The following general conclusions were drawn from the data obtained under the conditions described.

1. The ultimate tensile strength and modulus of rupture of papreg increased to a maximum and remained virtually constant as the laminating pressure was increased for all resin and volatile contents. The maximum was reached at lower molding pressures as the resin content was increased. The highest tensile strengths were obtained with the lowest resin content and the lowest volatile content.

2. The edgewise compressive strength of papreg increased to a maximum and then remained constant as the laminating pressure was increased for all resin and volatile contents. The compressive strength was increased as the resin content was increased and the highest values were obtained with the lowest volatile content.

3. The moduli of elasticity, in tension, compression and bending, increased to a maximum and then remained substantially constant as the laminating pressure was increased for all resin and volatile contents. The maximums were reached at lower molding pressures as the resin content was increased. The highest values were obtained at the lowest resin content. No significant trends because of changes in volatile content were evident.

4. The specific gravity of papreg increased to a maximum and remained nearly constant as the laminating pressure was increased for all resin and volatile contents. The maximum specific gravity was reached at lower laminating pressures as the resin content was increased. No appreciable effect on this property was observed by changes in volatile content at 40 percent resin content.

5. The water absorption of papreg decreased as the resin content was increased. In fact, resin content was the most important factor in reducing the water absorption. This was especially noticeable in the low range of laminating pressure. Increasing laminating pressure appreciably affected this property only at the lowest resin content. The water absorption was decreased with increased volatile content only in the low range of resin content.

Table 1.--Ultimate tensile strength of papreg (Series 2037) as affected by resin and volatile contents and laminating pressure[1]

Laminating pressure	Resin content -- percent								
	27			35			40		
	Volatile content -- percent								
	4.0	5.5	7.0	4.0	5.5	7.0	4.0	5.5	7.0
Lb. per sq. in.	Lb. per sq. in.			Lb. per sq. in.			Lb. per sq. in.		
25	30,310	29,993	30,240	29,547	30,223	----	31,690	27,940	----
50	33,043	32,210	32,883	33,943	34,740	32,357	36,293	35,623	33,273
75	34,310	32,103	33,917	34,907	33,847	34,567	36,053	35,267	34,867
100	35,957	35,220	33,887	35,877	37,630	36,900	37,197	37,607	35,203
125	36,370	36,330	36,330	37,087	38,417	37,037	38,300	37,303	36,367
150	35,863	38,230	37,670	39,370	40,353	38,377	38,323	36,190	34,847
175	36,090	37,700	40,683	38,360	41,070	41,010	37,313	37,610	----
200	37,200	38,427	39,600	39,920	39,110	39,540	39,080	37,237	38,240
250	39,273	37,647	37,920	42,140	40,340	36,590	35,470	35,645	39,255
500	44,510	43,510	42,593	42,287	40,857	41,520	39,900	41,330	----
1000	45,060	43,495	40,475	41,920	40,330	39,590	36,760	40,610	38,210
2000	----	42,890	43,377	44,440	45,690	43,833	39,730	40,393	----

[1] Mitscherlich base paper, parallel laminated at 325° F. for 12 minutes. Tested parallel to grain according to "Proposed Federal Specification for Organic Plastics; General Specification (Methods of Physical Tests)" July 7, 1942.

Table 2.--Ultimate compressive strength of papreg (Series 2037) as affected by resin and volatile contents and laminating pressure[1]

Laminating pressure	Resin content -- percent								
	27			35			40		
	Volatile content -- percent								
	4.0	5.5	7.0	4.0	5.5	7.0	4.0	5.5	7.0
Lb. per sq. in.	Lb. per sq. in.			Lb. per sq. in.			Lb. per sq. in.		
25	13,160	13,880	15,480	14,030	14,920	----	19,760	16,530	----
50	16,120	16,060	16,000	17,150	18,150	16,860	20,690	19,270	18,960
75	16,300	17,022	16,080	19,180	18,900	17,720	20,670	18,530	19,430
100	18,230	17,850	17,900	21,060	20,120	19,938	22,140	22,380	21,290
125	----	17,425	18,217	21,392	20,480	19,860	23,640	21,960	21,060
150	18,460	18,180	18,280	21,370	21,220	20,320	22,823	22,200	21,630
175	19,420	17,153	18,600	23,220	22,810	22,380	24,900	23,620	----
200	19,540	20,350	19,230	23,740	21,082	22,120	24,320	23,800	22,340
250	19,885	20,000	19,730	23,058	22,400	21,540	23,850	24,100	22,480
500	22,780	22,060	20,300	23,600	21,480	22,270	24,440	22,560	----
1000	24,630	23,990	22,380	23,320	24,390	22,640	24,600	23,470	23,070
2000	21,290	22,790	21,610	24,290	22,687	22,225	23,307	21,407	----

[1]Mitscherlich base paper parallel laminated at 325° F. for 12 minutes. Tested edgewise, parallel to grain, according to "Proposed Federal Specification for Organic Plastics; General Specification (Methods of Physical Tests)" July 7, 1942.

Table 3.--Modulus of rupture of papreg (Series 2037) as affected by resin and volatile contents and laminating pressure[1]

Laminating pressure	Resin content -- percent								
	27			35			40		
	Volatile content -- percent								
	4.0	5.5	7.0	4.0	5.5	7.0	4.0	5.5	7.0
Lb. per sq. in.	Lb. per sq. in.			Lb. per sq. in.			Lb. per sq. in.		
25	25,680	28,700	32,180	29,990	27,560	----	29,890	29,020	----
50	26,270	29,520	30,720	31,400	30,200	31,700	33,560	32,970	29,500
75	32,060	31,540	31,500	32,520	33,040	33,600	35,380	33,500	31,030
100	33,820	32,750	31,990	33,580	32,360	33,153	35,775	33,155	30,040
125	33,420	33,530	33,197	35,550	36,950	36,740	35,880	34,997	34,810
150	34,970	35,220	33,200	37,240	37,700	35,755	36,700	34,637	33,910
175	38,380	36,270	36,850	38,500	38,800	37,970	38,100	36,400	----
200	37,430	37,120	36,920	38,600	38,380	35,900	38,540	37,020	36,080
250	39,080	39,430	38,420	41,420	38,860	39,480	38,640	36,280	37,180
500	41,670	41,820	40,470	40,740	39,340	39,570	38,880	38,920	----
1000	41,510	41,300	40,200	40,980	38,240	39,240	38,180	38,200	38,000
2000	44,200	42,700	41,900	40,800	40,980	41,440	37,530	37,000	----

[1]Mitscherlich base paper parallel laminated at 325° F. for 12 minutes. Tested parallel to grain according to "Proposed Federal Specification for Organic Plastics; General Specification (Methods of Physical Test)" July 7, 1942.

Table 4.--Moduli of elasticity of papreg (Series 2037) in tension, compression and bending as affected by resin and volatile contents and laminating pressure[1]

Resin content -- percent: 27

Laminating pressure	Volatile content -- percent: 4.0			5.5			7.0		
	Tension	Compression	Bending	Tension	Compression	Bending	Tension	Compression	Bending
Lb. per sq. in.	1000 pounds per square inch								
25	2456	2520	2280	2612	2567	2364	2724	2639	2594
50	3073	2774	2509	3087	2782	2555	3132	2802	2640
75	3185	2836	2679	3004	2745	2682	3062	2839	2720
100	3060	2957	2654	3156	2928	2772	3126	2915	2752
125	3200	2936	2848	3368	2946	2876	3426	2981	2928
150	3440	3060	2800	3426	3078	2803	3648	3009	2852
175	3419	3073	3175	3402	3032	3077	3525	3036	3202
200	3490	3158	3150	3218	3094	3145	3496	3090	3234
250	3945	3096	3234	3914	3142	3165	3664	3172	3292
500	3555	3356	3626	3806	3504	3560	3576	3339	3508
1000	3946	3215	3565	3877	3378	3525	3750	3240	3500
2000	3935	3575	3702	3968	3621	3558	3985	3450	3644

Resin content -- percent: 35

Laminating pressure	Volatile content -- percent: 4.0			5.5			7.0		
	Tension	Compression	Bending	Tension	Compression	Bending	Tension	Compression	Bending
Lb. per sq. in.	1000 pounds per square inch								
25	2606	2363	2340	2578	2382	2355	----	----	----
50	3153	2860	2561	3090	2349	2482	3127	2640	2584
75	3128	2866	2826	3299	2839	2877	3124	2816	2804
100	3274	2561	2738	3258	2942	2716	3195	2912	2774
125	3444	3155	2948	3410	3016	3058	3267	2957	2954
150	3628	3049	2941	3514	3146	2908	3529	3050	2990
175	3429	2981	3150	3458	3100	3194	3464	3089	3260
200	3171	3141	3318	3350	3072	3172	3312	3073	3119
250	3746	3186	3390	3563	3140	3084	3541	3120	3198
500	3650	3261	3279	3371	3148	3219	3486	3294	3224
1000	3690	3229	3329	3689	3190	3296	3760	3344	3354
2000	3670	3294	3300	3650	3262	3420	3790	3452	3466

Resin content -- percent: 40

Laminating pressure	Volatile content -- percent: 4.0			5.5			7.0		
	Tension	Compression	Bending	Tension	Compression	Bending	Tension	Compression	Bending
Lb. per sq. in.	1000 pounds per square inch								
25	2706	2617	2372	2508	2515	2276	----	----	----
50	3176	2778	2658	3116	2806	2607	2940	2577	2400
75	3156	2862	2809	3110	2723	2746	3018	2717	2708
100	3057	2907	2759	2999	2875	2695	3008	2769	2584
125	3250	2902	2882	3104	2940	2776	3188	2860	2851
150	3350	3121	2841	3308	2962	2806	3686	2842	2721
175	3156	2940	3012	3300	2808	2894	----	----	----
200	3129	2877	2943	----	2800	3040	3176	2978	3026
250	3252	2926	3012	3369	2962	2958	3348	3000	2966
500	3098	2964	2978	3360	2966	3093	----	----	----
1000	3405	2871	3032	3490	3080	3089	3505	3144	3213
2000	3374	2976	3078	3426	3134	3119	----	----	----

[1] Mitscherlich base paper parallel laminated at 325° F. for 12 minutes. Tests made parallel to grain according to "Proposed Federal Specification for Organic Plastics; General Specification (Methods of Physical Tests)" July 7, 1942.

Z M 50582 F

Table 5.--Specific gravity of papreg (Series 2037) as affected by resin and volatile contents and laminating pressure[1]

Laminating pressure	Resin content -- percent								
	27			35			40		
	Volatile content -- percent								
	4.0	5.5	7.0	4.0	5.5	7.0	4.0	5.5	7.0
Lb. per sq. in.	Lb. per sq. in.			Lb. per sq. in.			Lb. per sq. in.		
25	1.08	1.09	1.11	1.14	1.16	----	1.25	1.20	----
50	1.14	1.16	1.16	1.22	1.24	1.25	1.34	1.33	1.30
75	1.20	1.20	1.21	1.28	1.31	1.31	1.36	1.36	1.36
100	1.20	1.22	1.23	1.28	1.32	1.32	1.37	1.36	1.35
125	1.23	1.26	1.28	1.32	1.35	1.37	1.38	1.39	1.39
150	1.23	1.27	1.26	1.32	1.37	----	1.38	1.38	1.38
175	1.30	1.30	1.32	1.37	1.40	1.40	1.39	[illegible]	----
200	1.28	1.31	1.34	1.37	1.40	1.40	1.40	1.40	1.40
250	1.33	1.34	1.37	1.40	1.41	1.41	1.40	1.40	1.40
500	1.40	1.42	1.42	1.41	1.42	1.42	1.40	1.40	----
1000	1.43	1.43	1.43	1.42	1.42	1.43	1.41	1.42	1.42
2000	1.44	1.44	1.44	1.42	1.43	1.43	1.41	1.41	----

[1] Mitscherlich base paper parallel laminated at 325° F. for 12 minutes. Test value based on weight and volume at time of test.

Table 6.--Water absorption of papreg (Series 2037) as affected by resin and volatile contents and laminating pressure[1]

Laminating pressure	Resin content -- percent																	
	27						35						40					
	Volatile content -- percent						Volatile content -- percent						Volatile content -- percent					
	4.0		5.5		7.0		4.0		5.5		7.0		4.0		5.5		7.0	
	Water absorption	Flash	Water absorption	Flash	Water absorption	Flash	Water absorption	Flash	Water absorption	Flash	Water absorption	Flash	Water absorption	Flash	Water absorption	Flash	Water absorption	Flash
Lb. per sq. in	Percent						Percent						Percent					
25	21.3	0	13.1	0	15.9	0	8.1	0	6.2	0.3	---	1.4	3.7	0	3.8	1.3	---	3.8
50	11.0	0	11.3	0	8.3	0.4	5.6	0	4.5	1.0	4.1	2.0	3.4	0.3	3.1	1.3	2.8	4.2
75	9.8	0	8.2	0	6.8	0.7	4.4	0.3	3.7	1.3	4.8	1.4	3.0	0.3	2.7	1.9	2.6	5.1
100	8.3	0	6.6	0	5.5	---	4.4	0.3	3.7	1.0	3.6	1.7	3.0	0.3	2.7	2.2	2.9	6.4
125	8.6	0	5.8	0	4.8	0.7	4.2	0.3	3.5	1.0	3.2	1.0	2.9	0.3	2.6	2.5	2.6	8.7
150	9.1	0	5.7	0	4.8	0.7	4.1	0.3	3.3	1.4	3.4	2.0	2.9	0.6	2.6	3.2	2.6	6.5
175	6.5	0	5.8	0.4	4.6	0.7	4.0	0.3	3.2	1.7	3.3	2.0	2.8	0.6	2.6	2.9	---	---
200	6.9	0	5.3	0.4	4.4	0.7	3.9	0.7	3.1	1.7	3.1	2.7	2.7	1.0	2.6	3.2	2.7	5.9+
250	6.1	0	5.2	0.4	4.3	1.1	3.9	0.7	3.3	1.7	3.3	2.4	2.8	1.0	2.7	4.2	2.9	8.2
500	5.2	0.4	4.7	0.7	4.2	1.5	4.7	1.0	3.3	2.4	3.6	4.2	2.8	1.6	2.9	5.3	---	---
1000	5.0	0.8	4.9	1.5	4.6	3.0	5.0	1.7	3.7	4.2	3.8	6.4	2.7	2.6	3.4	6.7	3.4	11.5+
2000	5.5	1.1	5.0	2.6	5.0	4.6	4.1	2.1	3.9	5.3+	4.4	8.0+	2.7	4.6	3.4	9.9	---	---

[1] Mitscherlich base paper, parallel laminated at 325° F. for 12 minutes. Water-absorption specimen cut with grain in long dimension and tested according to "Proposed Federal Specification for Organic Plastics; General Specification (Methods of Physical Tests)" July 7, 1942.

Z M 50583 F

Figure 1.--The Forest Products Laboratory resin impregnator and dryer, for preparing laminating paper.

Z M 50573 F

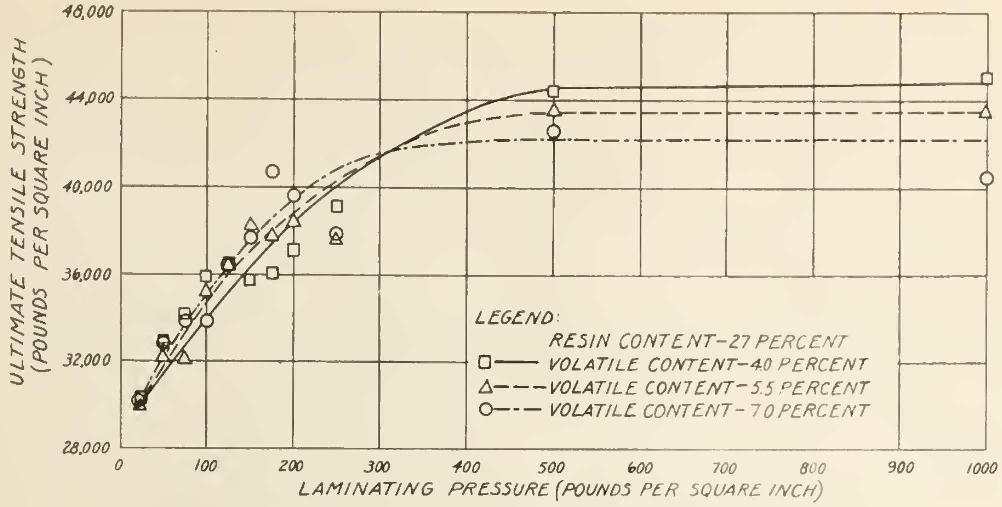


Figure 2.--Ultimate tensile strength of papreg at three volatile content values and at a resin content of 27 percent.

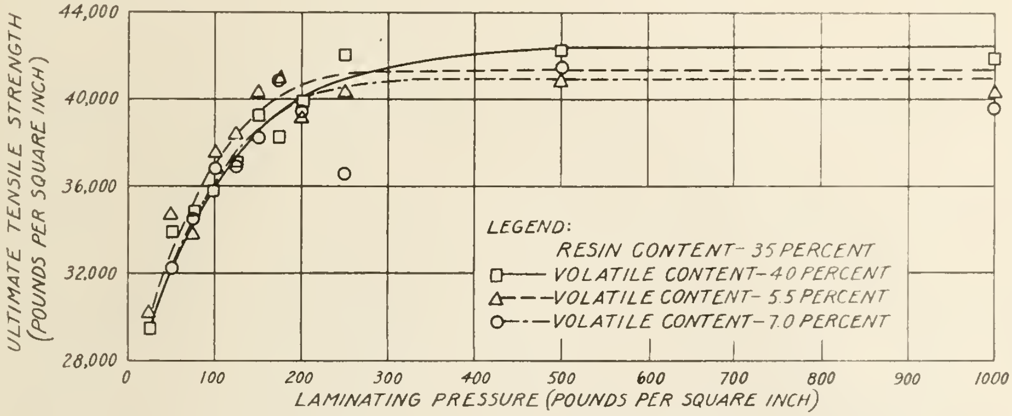
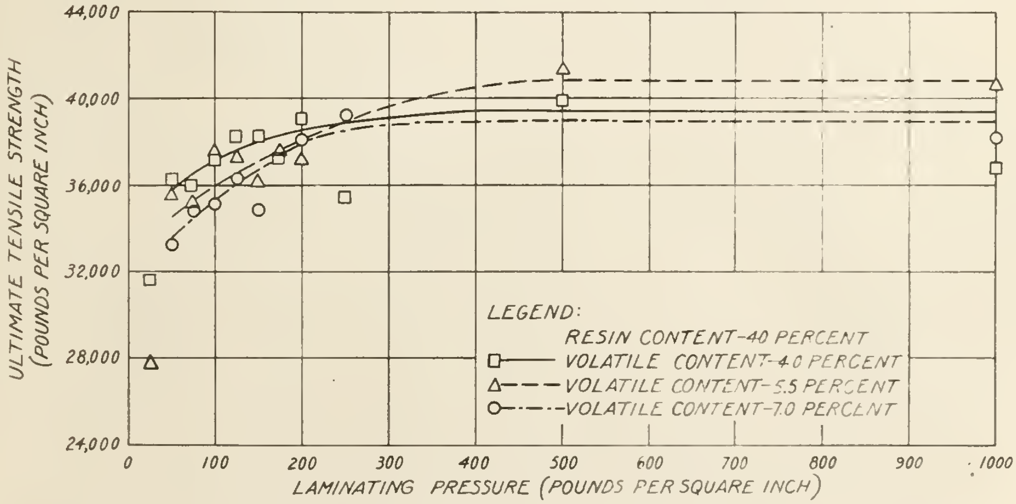


Figure 3.--Ultimate tensile strength of papreg at three volatile content values and at a resin content of 35 percent.



Z M 50574 F

Figure 4.--Ultimate tensile strength of papreg at three volatile content values and at a resin content of 40 percent.

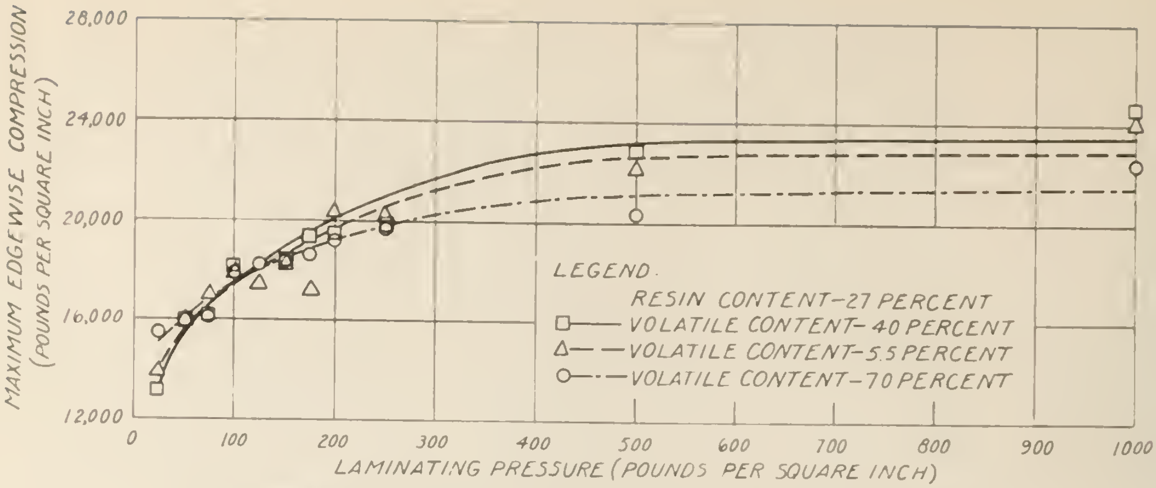


Figure 5.--Maximum-edgewise-compression values of papreg at three volatile content values and at a resin content of 27 percent.

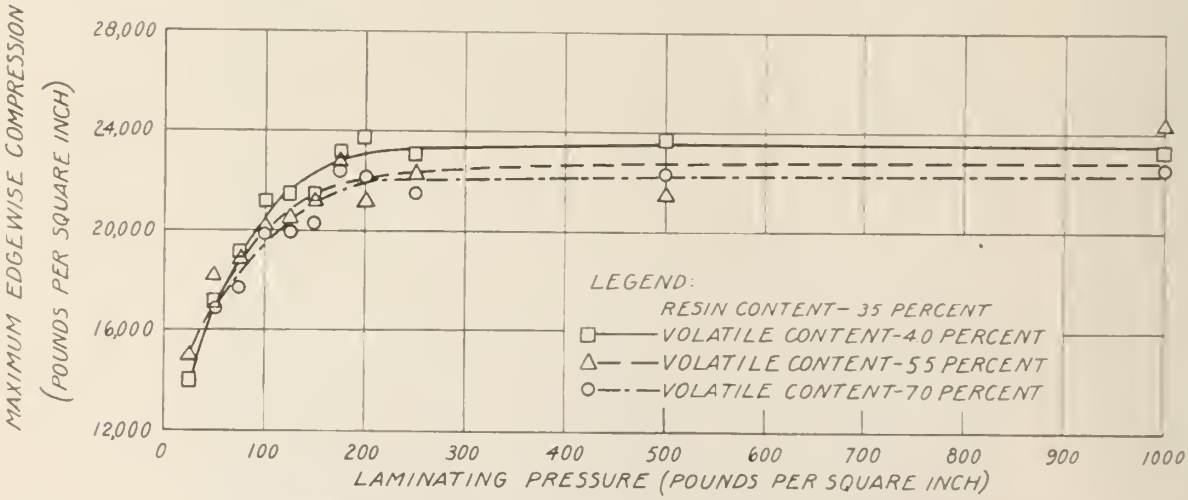


Figure 6.--Maximum-edgewise-compression values of papreg at three volatile content values and at a resin content of 35 percent.

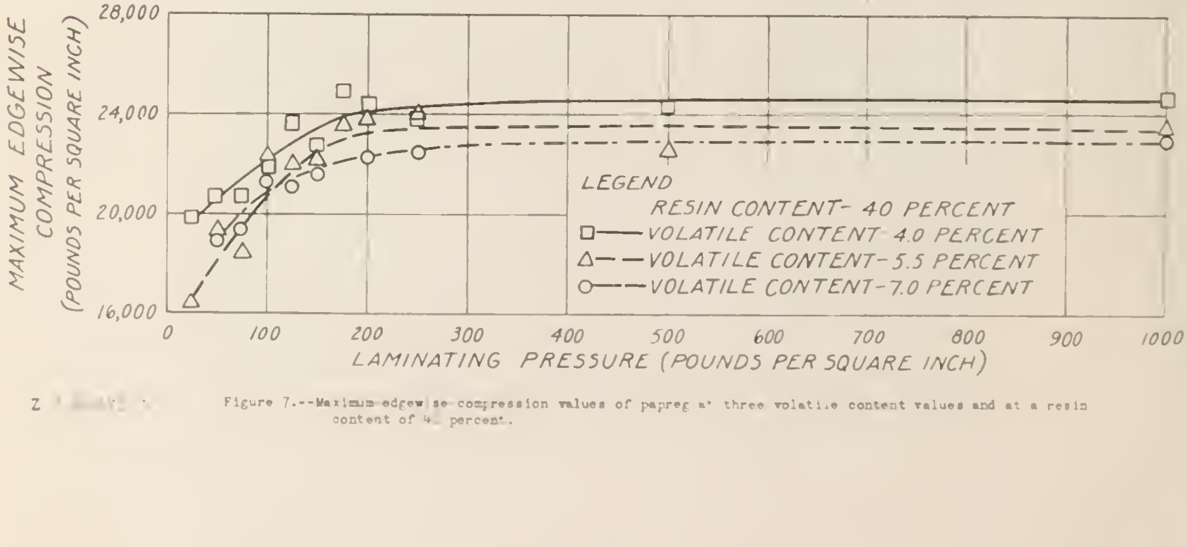


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Figure 7.--Maximum-edgewise-compression values of papreg at three volatile content values and at a resin content of 40 percent.

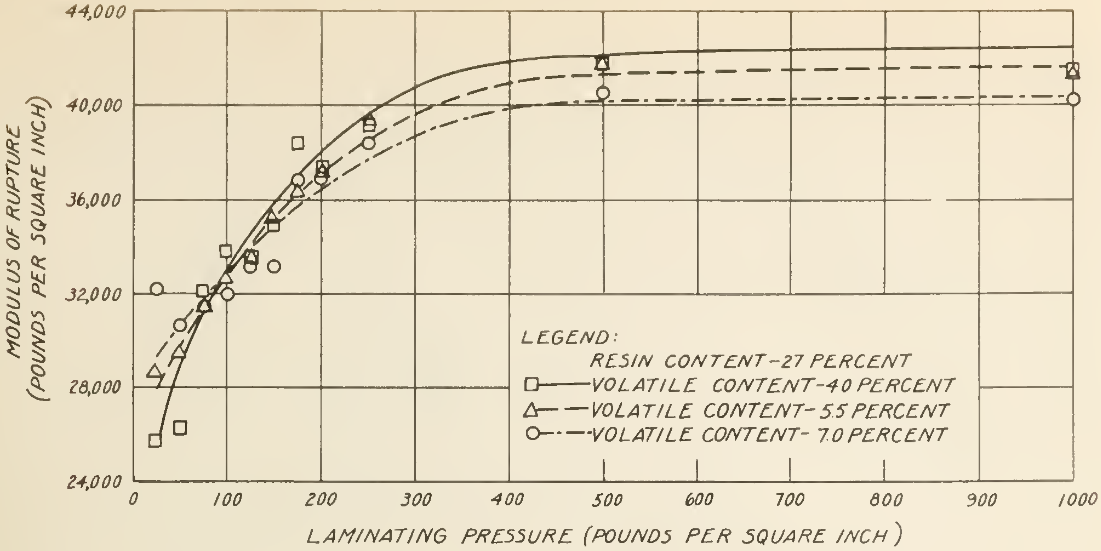


Figure 8.--Modulus of rupture of papreg at three volatile content values and at a resin content of 27 percent.

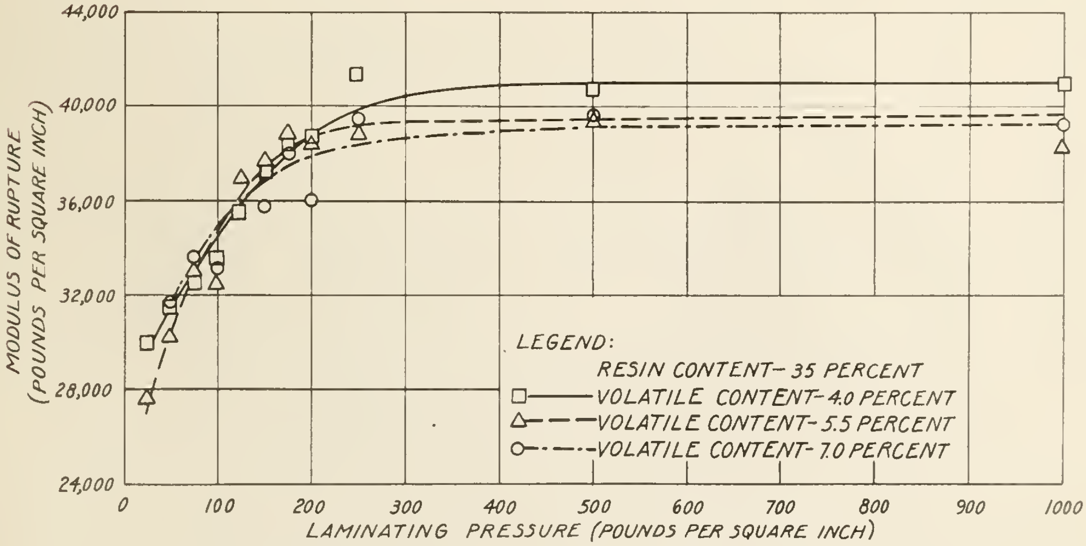
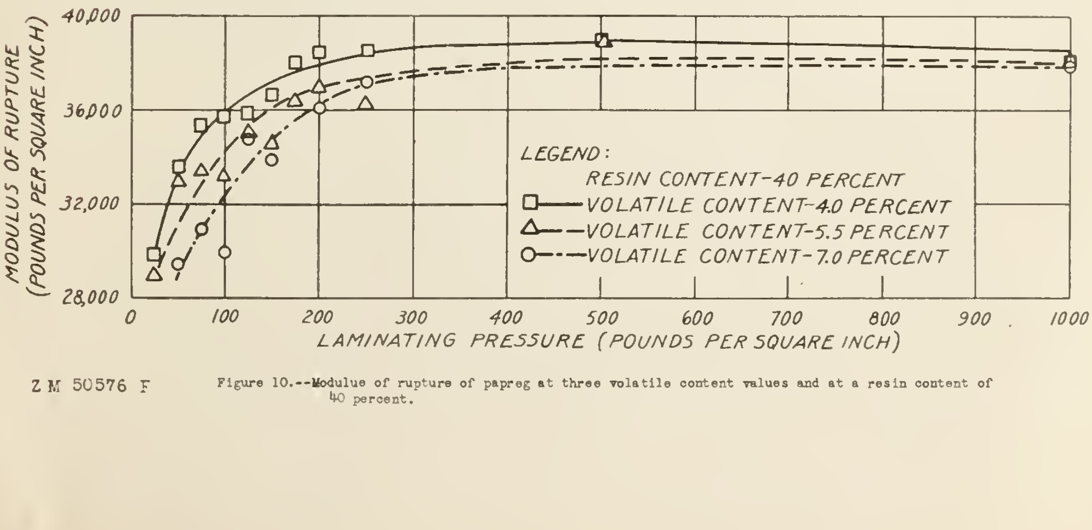


Figure 9.--Modulus of rupture of papreg at three volatile content values and at a resin content of 35 percent.



Z M 50576 F

Figure 10.--Modulus of rupture of papreg at three volatile content values and at a resin content of 40 percent.

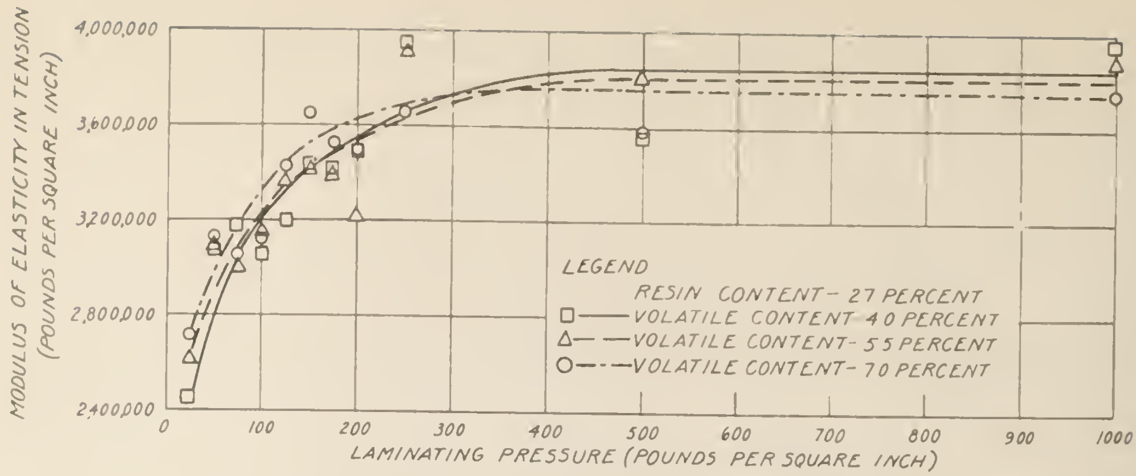


Figure 11.--Modulus of elasticity in tension of papreg at three volatile content values and at a resin content of 27 percent.

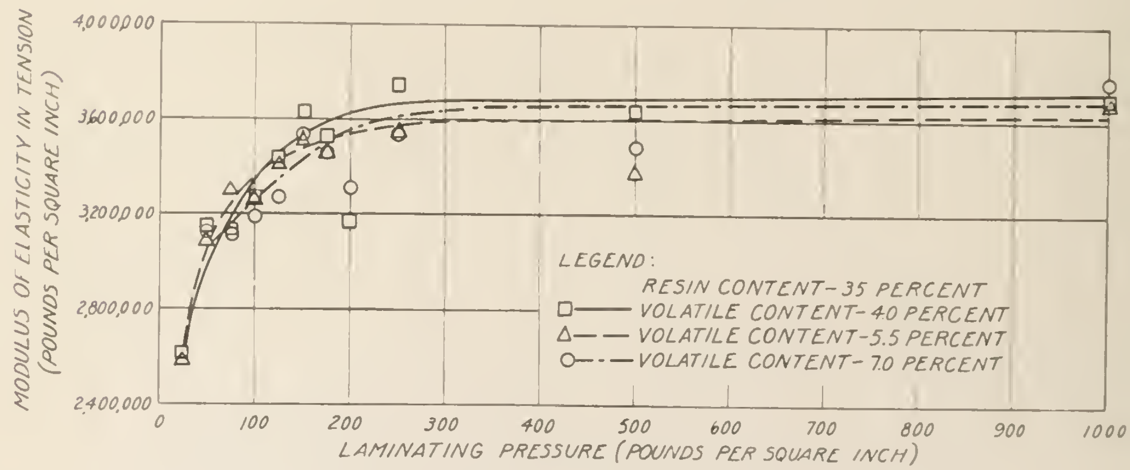
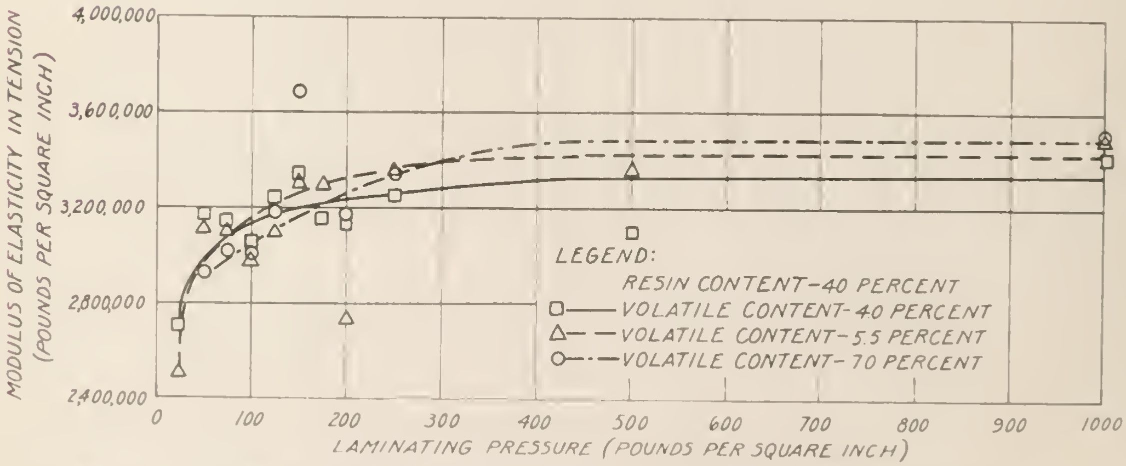


Figure 12.--Modulus of elasticity in tension of papreg at three volatile content values and at a resin content of 35 percent.



Z M [illegible] 577 F

Figure 1[illegible].--Modulus of elasticity in tension of papreg at three volatile content values and at a resin content of [illegible] percent.

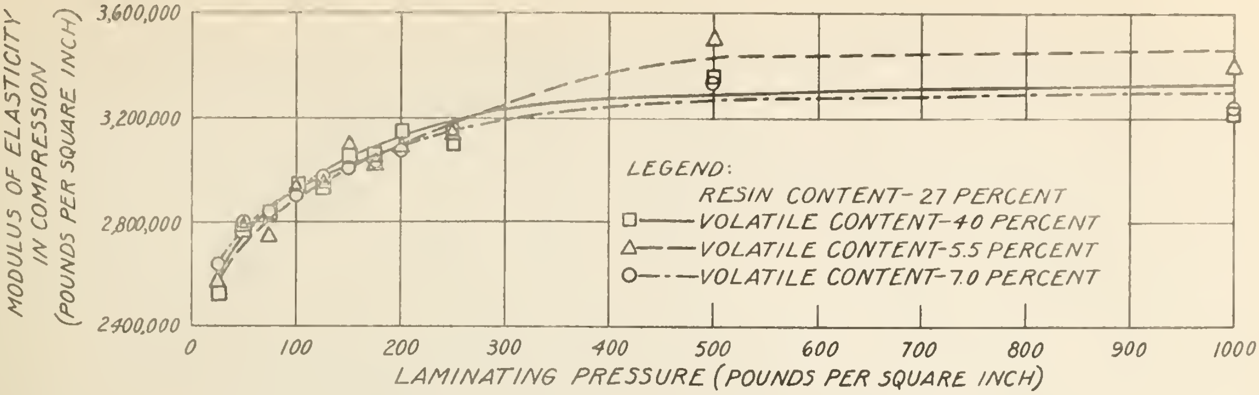


Figure 14.--Modulus of elasticity in compression of papreg at three volatile content values and at a resin content of 27 percent.

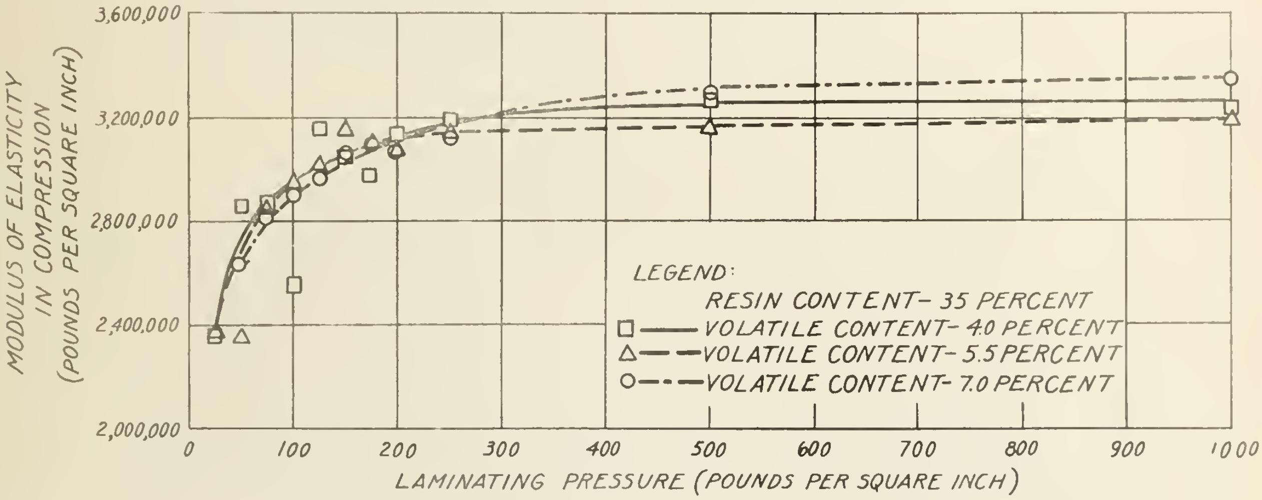
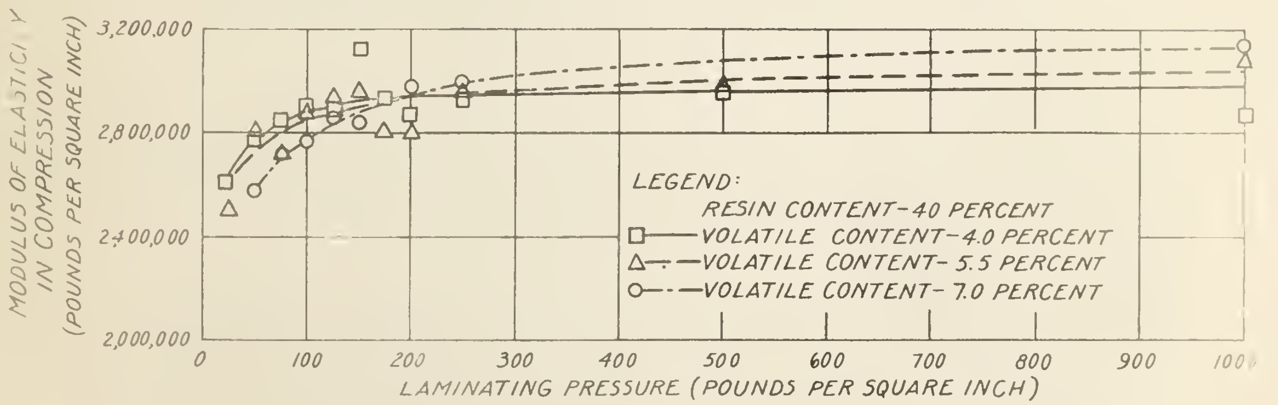


Figure 15.--Modulus of elasticity in compression of papreg at three volatile content values and at a resin content of 35 percent.



Z M 50578 F

Figure 16.--Modulus of elasticity in compression of papreg at three volatile content values and at a resin content of 40 percent.

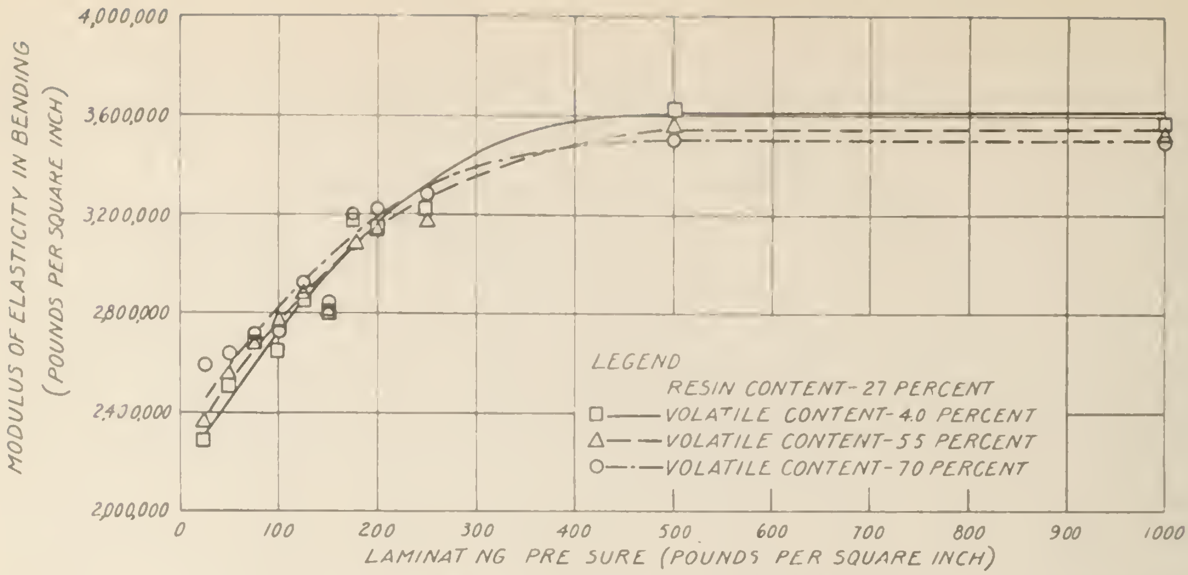


Figure 17.--Modulus of elasticity in bending of papreg at three volatile content values and at a resin content of [illegible] percent.

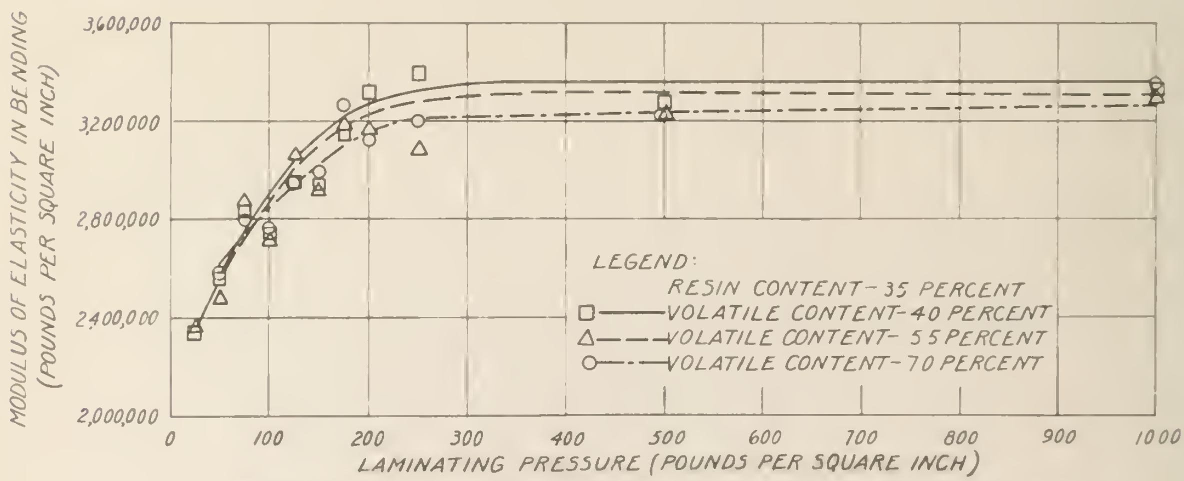
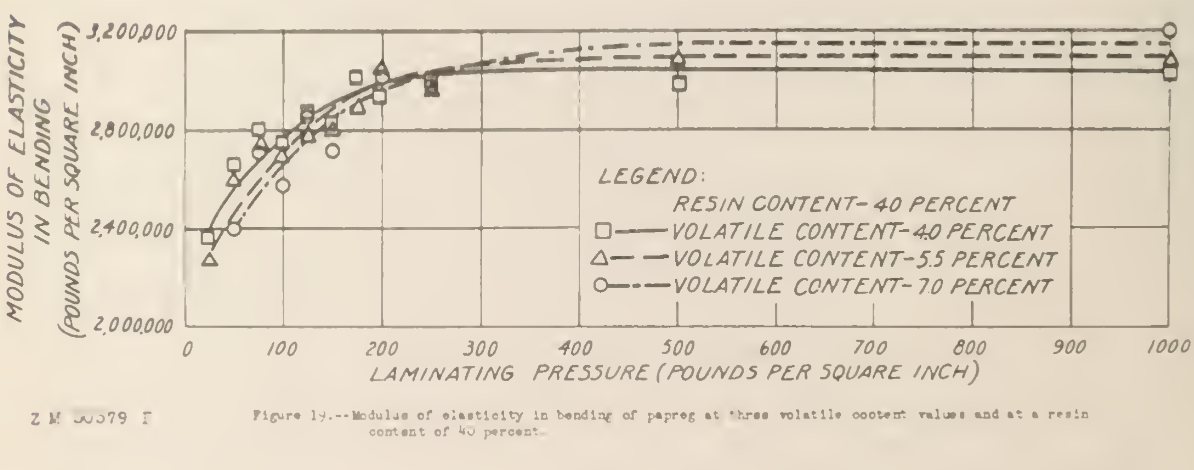


Figure 18.--Modulus of elasticity in bending of papreg at three volatile content values and at a resin content of 35 percent.



Z M [illegible]579 F

Figure 19.--Modulus of elasticity in bending of papreg at three volatile content values and at a resin content of 40 percent.

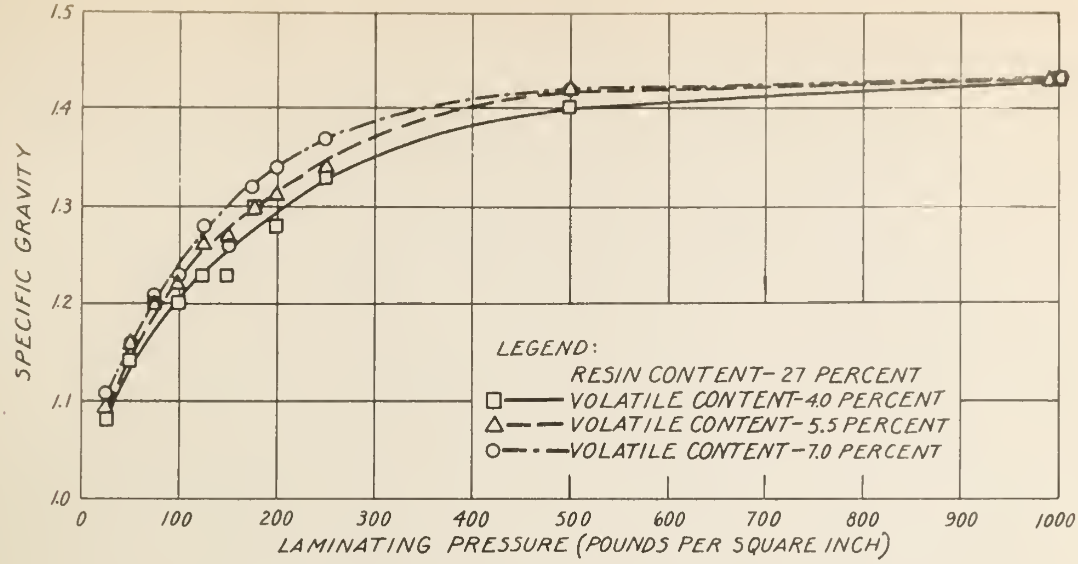


Figure 20.--Specific gravity of papreg at three volatile content values and at a resin content of 27 percent.

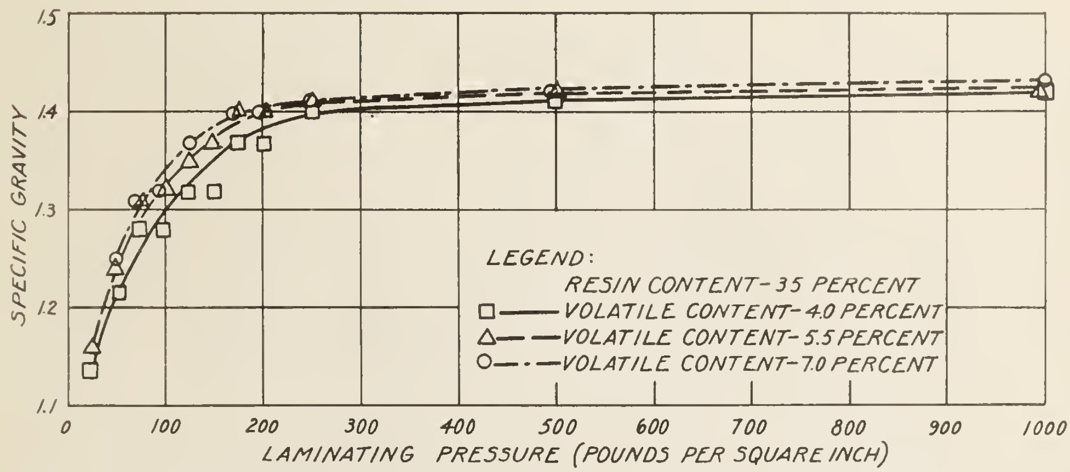
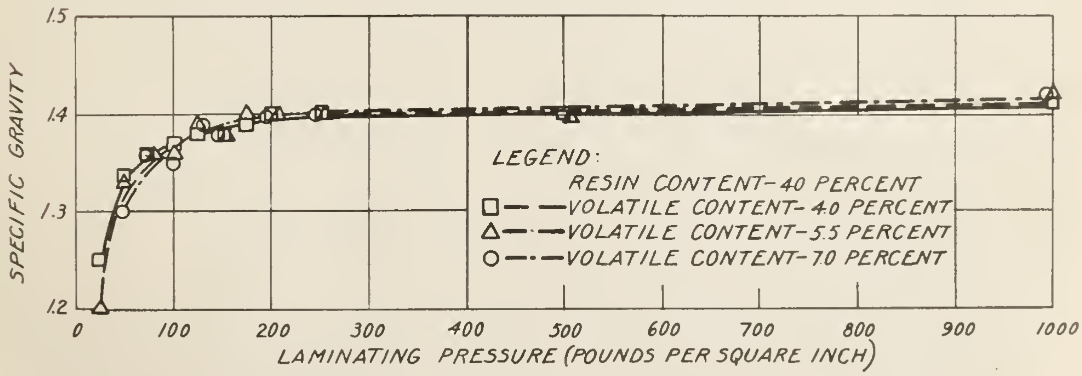


Figure 21.--Specific gravity of papreg at three volatile content values and at a resin content of 35 percent.



Z M 50580 F

Figure 22.--Specific gravity of papreg at three volatile content values and at a resin content of 40 percent.

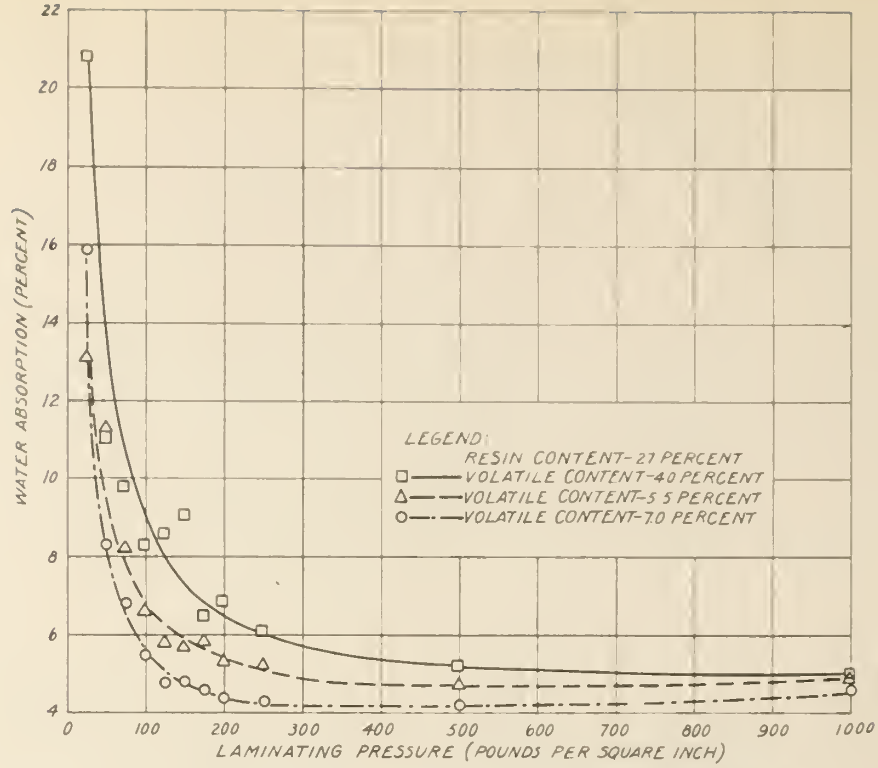


Figure 23.--Water absorption of papreg at three volatile content values and at a resin content of 27 percent.

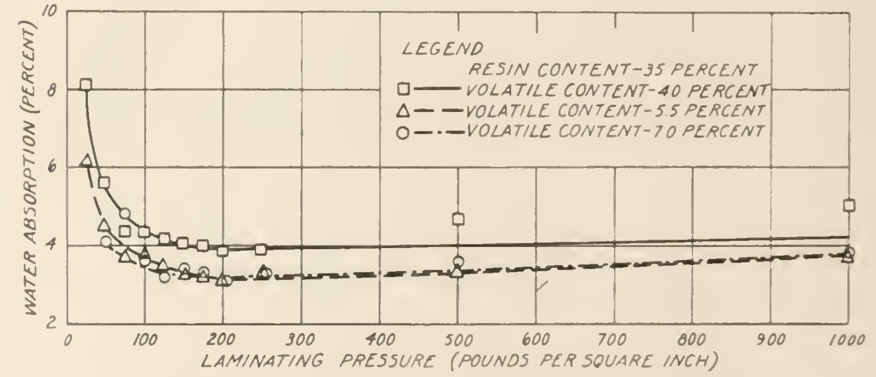
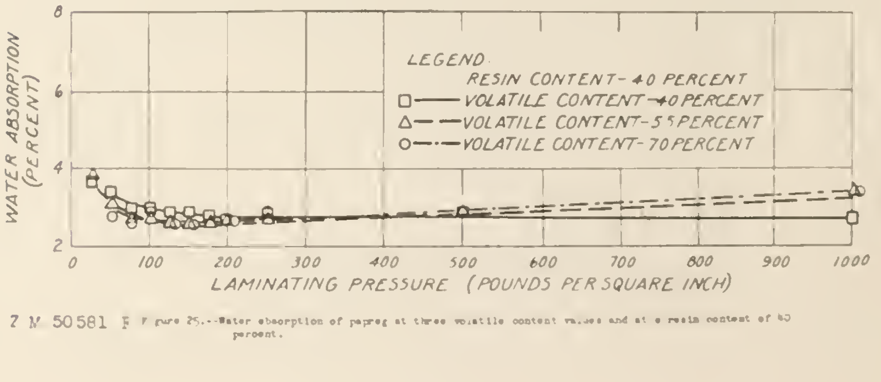


Figure 24.--Water absorption of papreg at three volatile content values and at a resin content of 35 percent.



Z M 50581 F

Figure 25.--Water absorption of papreg at three volatile content values and at a resin content of 40 percent.